CRITERION 428

POLYMER SEALS IN RADIOLOGICAL SERVICE

SIGNATURES

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RECORD OF REVISIONS

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POLYMER SEALS IN RADIOLOGICAL SERVICE

1.0 PURPOSE

The purpose of this criterion is to establish the minimum requirements and best practices for maintaining polymeric seals in radiological service.

This document addresses the requirements of LIR 230-05-01, "Operations and Maintenance Manual." (Reference 1)

2.0 SCOPE

The scope of this criterion is to address preventive maintenance of polymer (e.g., Teflon) seals when they are exposed to cumulative levels of radiation of 10^4 rads or greater and provide a barrier to confine hazardous materials.

The LANL complex has approximately 18 nuclear facilities and 59 radiological facilities. Each of these facilities uses seals on valves, pipe/tubing joints, and rotating shafts.

This criterion does not address corrective maintenance actions required to repair or replace equipment. Glovebox gloves are excluded from the scope of this criterion.

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

AR	Administrative Requirements
CFR	Code of Federal Regulations
CMMS	Computerized Maintenance Management System
EPDM	Ethylene Propylene Diene Monomer
LIR	Laboratory Implementing Requirement
LIG	Laboratory Implementing Guidance
O&M	Operations and Maintenance
PP&PE	Personal Property and Programmatic Equipment
RAD	Radiation Absorbed Dose
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems, and Components
TFE	Tetrafluoroethylene (e.g., Teflon™)
UC	University of California

3.2 Definitions

Elastomer: A polymeric material, such as a synthetic rubber or plastic, which at room temperature can be stretched under low stress to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length. (Reference McGraw-Hill Dictionary of Science and Technology Terms 5th Ed.)

Polymer: A substance made of giant molecules formed by the union of simple molecules (monomers). (Reference McGraw-Hill Dictionary of Sci and Tech Terms 5th Ed.)

Rad: A unit of absorbed dose equal to 100 ergs/g.

Seal: Devise for closing a gap or making a joint fluid tight.

Seal, Dynamic: Sealing between surfaces that have relative movement.

Seal, Static: Sealing between surfaces that do not move relative to one another.

Teflon: General trademark of the Du Pont Company for its fluorocarbon polymer.

4.0 RESPONSIBILITIES

4.1 FWO-Systems Engineering and Maintenance (SEM)

4.1.1 Responsible for the technical content of this criterion and assessing the proper implementation across the Laboratory.

4.1.2 Provide technical assistance to support implementation of this criterion.

4.2 Facility Manager

4.2.1 Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE), in accordance with the requirements of this document.

4.2.2 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

4.2.3 Responsible for system performance analysis and subsequent replacement or refurbishment of RP&IE and assigned PP&PE based on sound life cycle analysis techniques and system-specific performance requirements.

4.3 Programmatic Group Leaders

4.3.1 Responsible for system performance analysis and for implementing operational and maintenance surveillance programs including the preparation and maintenance of required procedures and documentation for PP&PE under their jurisdiction that is covered by this criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this criterion. A compilation of all applicable precautions shall be contained in the implementing procedure (s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards/precautions that may not be immediately obvious.

5.1.1 Follow an approved Work Package or Hazard Control Plan when inspecting or replacing irradiated seals.

5.2 Limitations

The intent of this criterion is to identify the minimum generic requirements and best practices for SSC operation and maintenance across the Laboratory. Each user is responsible for the identification and implementation of additional facility-specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, vendor O&M requirements and guidance, etc.).

Nuclear facilities and moderate to high-hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this criterion. Nuclear facilities shall implement the requirements of DOE Order 4330.4B (or 10 CFR 830.340, Maintenance Management, when issued) (Reference 2) as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or CFR identified above.

Because of the damage caused by radiation, polymeric seals have limited value in high radiation applications. Detailed polymer and metal seal application information can be found in the Facility Engineering Manual, Chapter 6. (Reference 8)

6.0 REQUIREMENTS

Minimum requirements that criterion users must follow are specified in this section. Requested variances to these requirements must be prepared and submitted to FWO-SEM in accordance with LIR301-00-02, "Variances and Exceptions to Laboratory Operations Requirements" (Reference3) for review and approval. The implementation of these requirements will ensure that the subject SSC is maintained in accordance with contractual requirements. The criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. The requirements contained in this section are driven by laws, codes, contractual requirements, engineering judgement, safety matters, and operations and maintenance experience.

6.1 Operations Requirements

6.1.1 A graded approach shall be used for operations with polymeric sealing materials that are utilized in radioactive environments. A conservative estimate shall be made of the accumulated dose that will be incurred on the component during its operating lifetime in the radiation environment. If the conservative estimate of the dose is less than one half of the damage threshold for a material that provides a safety barrier whose failure could result in the release of radioactive contamination, then no inventory of the item is required and no actions other that routine maintenance and replacement of the item is required.

If the polymer sealing material used in a process operation does not provide a direct safety barrier, or the conservative estimate of the accumulated dose over the components intended lifetime is less than the damage threshold, then no further actions are required except the execution of the routine maintenance program.

For polymeric sealing materials that provide a safety barrier and the estimate of the accumulated dose exceeds one half of the damage threshold or polymeric sealing materials in process applications where the estimated dose exceeds the damage threshold, then a more extensive program of inventory, tracking, and management is required. All affected polymeric components shall be inventoried and a database of these components shall be maintained. Methods shall be implemented for the determination of the length of suitability of the material for service. Methods should incorporate a direct measurement of the radiation if possible. Where a direct measurement of the dose is not possible other methods, such as function testing, to determine that the continued integrity of the barrier material shall be implemented.

In situations where high doses are potentially incurred, it is best practice to provide multiple barriers to minimize the incurred dose. This includes items such as filters on extraction lines between the glovebox and a polymeric sealing material in a valve or coverings and coatings for other sealing surfaces.

Basis: Seals that could fail and not lead to unacceptable releases are outside of the scope. Notice 51 (Reference 10.4) requires identification of Teflon

because it was the material that failed in the ball valve in the 3/2000 TA-55 incident; yet, a similar failure could occur with any polymer as they all sustain damage due to radiation; however, their resistance to radiation damage may be such that 10^4 in air is too low a threshold for concern.

6.2 Maintenance Requirements

6.2.1 Seals and sealing material that are inventoried and have accumulated a dose in excess of one half of the damage threshold shall have a program in place to monitor and ensure their continued performance. It is the best practice to replace materials before they have reached the accumulated dose to cause a 25% degradation in material properties or an accumulated radiation dose of 3.7 $x10^4$ rads for Teflon. The damage thresholds for some other polymeric materials are shown in Table 6.2-1.

Note: Common trade and commercial names of Teflon™-like materials include: Algotlon, Duroid, Fluon, Fluorocomp, Gore-Tex, Halon TFE, Hostoflon TF, Kalrez perfluoroelastomer, Kel-F polychlorotrifluoroethylene, Neoflon, Polycomp, Polyflon, and Teflon™.

Basis: LANLs response to TA-55 Type A Investigation. (Reference 10.5) Laboratory Corrective Action Plan, LANL ID No. 00-019. (Reference 10.10) Teflon™ experiences significant degradation of many mechanical properties, including tensile strength, shear strength, elastic modulus, impact strength, and elongation at lower radiation exposure levels than most plastics. Table 6.2-1, extracted from the Materials Research Society's April 1997 Bulletin shows the impacts of penetrating gamma radiation exposure on Teflon™ relative to other common plastics.

6.2.2

Table 6.2-1 Relative Stability of Plastics

Material	Radiation Dosage for Threshold Damage (rad - gamma)	Radiation Dosage for 25% Damage (rad - gamma)
Polystyrene	8×10^8	4×10^9
Phenol formaldehyde (asbestos filler)	3.9×10^8	3.9×10^9
Polyester (mineral filler)	8.7×10^8	3.9×10^9
Polyvinyl Chloride	1.9×10^7	3.9×10^8
Polyethylene	1.9×10^7	9.3×10^7
Urea formaldehyde (unfilled)	8.3×10^6	5.1×10^7
Monochlorotrifluoro-ehthylene	1.2×10^6	2×10^7
Cellulose acetate	2.7×10^6	1.9×10^7
Phenol formaldehyde (unfilled)	2.7×10^6	1.1×10^7
Methyl methacrylate	8.2×10^5	1.1×10^7
Polyester (unfilled)	3.4×10^5	8.7×10^5
Polyetrafluoroethylene (Teflon™)	1.7×10^4	3.7×10^4

"Radiation Effects on Organic Materials," Nucleonics, Vol. 18, No. 9. (Reference 10.9)

Basis: Per DOE-HDBK-1132-99, (Reference 10.7) the general rule for elastomers used for sealing is that total radiation levels of 10^7 rads represent the warning point that elastomers may be losing their ability to maintain a seal. At 10^8 rads, virtually all elastomers used for sealing lose their ability to maintain a seal. Typical failures for penetrating exposure occur as a result of compression set (i.e., the elastomer becomes brittle and loses its ability to spring back). At 10^6 rads, on the other hand, the total damage is relatively minor, and most elastomers maintain their ability to maintain a seal. At 10^7 rads, the ability of an elastomer to maintain a seal becomes totally dependent on the chemical compounding of the elastomer in question. It only takes about two weeks for an elastomer to receive 10^7 rads at a dose rate of 2.88×10^4 rads/hr. Basis is not intended to imply high dose rates are acceptable or recommendable. Research on surface effects of alpha radiation is ongoing.

7.0 RECOMMENDATIONS AND GOOD PRACTICES

The information provided in this section is recommended based on acceptable industry practices, codes and standards, manufacturers recommendations, operating experience, DOE/LANL Lessons Learned program, or engineering judgement and should be implemented by each user based on his or her unique application and operating history of the subject systems/equipment.

7.1 Operations Recommendations

7.1.1 Polymeric seals are not recommended for use in radiological service where failure is unacceptable and either of the following apply:

- Conservative estimates of radiation exposure exceed the damage thresholds.
- Seal replacement cannot be performed before significant degradation might be expected of the polymeric material.

In these instances, metal seals are recommended. Metal seals are also preferable where outgassing or leakage is detrimental, such as in radioactive or toxic gas and high vacuum systems. The LANL Engineering Manual (Reference 10.8) Mechanical chapter provides additional information about seal selection.

An inventory of polymeric seals that potentially will incur a dose large than one half of the damage threshold and that provide a safety barrier will be maintained. A positive method to identify the seal will be provided in close proximity to the seal. This positive identification can be a barcode or other identifying symbol. Information in the inventory of these materials should include:

a. The location of the seal.

b. The type of the seal.

c. The expected time when the damage threshold is reached.

d. Preventive measures to determine the continued safety integrity of the sealing material.

e. Other relevant information.

Alternative materials to Teflon such as polyethylene, EPDM, and EPR, have radiation damage threshold values three to four orders of magnitude higher than that of Teflon. Based on the EPRI studies, these materials would supposedly not reach their radiation damage threshold for 1,000 to 10,000 times as long as Teflon. Qualitatively, PEEK is even more radiation resistant than polyethylene, EPDM, and EPR but by how much is not known. Selection of sealing material must be based on chemical and temperature compatibility in addition to performance in radiation environments.

Basis: LA-UR-00-5918, An Investigation and Literature Survey of the Performance of Teflon and other Elastomeric Materials in Radiolytic Environments, Project No. MTL-MS-00-025. (Reference 10.6)

7.2 Maintenance Recommendations

None.

8.0 GUIDANCE

This section provides guidance on how to implement the requirements and recommendations delineated in Sections 6.0 and 7.0 above. The intent is to provide guidance to the criterion user for the development and implementation of his or her program and to prevent each FMU/user from re-inventing the wheel for acceptable program development and implementation.

8.1 Operations Guidance

No implementing guidance available.

8.2 Maintenance Guidance

8.2.1 Damage Threshold Calculations

Conservative estimates should be made of the dose that any polymeric sealing materials will incur during their expected operating lifetime. These conservative estimates where possible should utilize measurements of the source term in the region of application. Mitigating factors such as filters should be taken account of in the estimates. Where neutron or gamma radiation may cause seal failures radiation surveys can be used to estimate the dose. The conservative estimates of dose along with the intended service lifetime should be compared to the damage thresholds to develop an estimate of the fraction of the threshold that the material would attain in its operating lifetime.

9.0 DOCUMENTATION

9.1 Required Documentation

Record keeping shall be consistent with the facility's Quality Assurance program.

- Seal inventory. (Section 7.1)
- Periodic Inspections.
- Expected time when damage threshold is resulted. (Section 7.1)
- Record of seal replacement.

Basis Notice 51 pages 4 and 5 and compliance with the requirements of 10 CFR 830.120. (Reference 10.11)

9.2 Recommended Documentation

None.

10.0 REFERENCES

The following references and associated revisions were used in the development of this document. Facility specific O&M procedures written to the requirements of this criterion should use the latest LANL approved revision of these documents.

10.1 LIR 230-05-01, "Operation and Maintenance Manual."

10.2 DOE Order 430.1A, Attachment 2, *"Contractor Requirements Document,"* (paragraph 2, sections A through C), a requirement of Appendix G of the UC Contract.

10.3 LIR 301-00-02.0, "Variances and Exceptions to Laboratory Operation Requirements."

10.4 LANL Notice No. 0051, "Teflon Sealing Material in Radiological Service/Compression Fitting Testing and Acceptance," 7/19/00.
http://labreq.lanl.gov/pdfs/ops/alerts/Notice0051.pdf#acrohls=http://labreq.lanl.gov/cgi-bin/w3vdkhgw?DSP=XML;qryIAAZ0QNU_;ops-10

10.5 *Type A Accident Investigation of the March 16, 2000 Plutonium-238 Multiple Intake Event at the Plutonium Facility*, Los Alamos National Laboratory, New Mexico, dated July 2000, DOE ES&H Office of Oversight.
http://tis.eh.doe.gov/oversight/reports/accidents/typea/0003lanl/index.html
[same as HQ-EH-2000-01].

10.6 *An Investigation and Literature Survey of the Performance of Teflon and other Elastomeric Materials in Radiolytic Environments*, by L. Dale Sivils/Michael Aire, C-ACT, LA-UR-00-5918, Project No. MTL-MS-00-025.

10.7 DOE Handbook 1132-99, *Design Considerations*.
http://tis.eh.doe.gov/techstds/standard/hdbk1132/hdbk113299.pdf

10.8 LANL (Facility) Engineering Manual (LIR 220-03-01.1), Chapter 6 - Mechanical, January 2001.

10.9 Nucleonics, Vol. 18, No.9, *"Radiation Effects on Organic Materials,"* Carroll, J.G., and Bolt, R.O., September 1960, p.73.

10.10 Laboratory Corrective Action Plan, LANL ID No. 00-019.

10.11 10 CFR 830.120, Maintenance Management.

11.0 ATTACHMENTS

None.